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HealthcareLCA: an open-access living database of health-care environmental impact assessments

Jonathan Drew, Sean D Christie, Daniel Rainham, Chantelle Rizan

Anthropogenic environmental change negatively affects human health and is increasing health-care system demand. Paradoxically, the provision of health care, which itself is a substantial contributor to environmental degradation, is compounding this problem. There is increasing willingness to transition towards sustainable health-care systems globally and ensuring that strategy and action are informed by best available evidence is imperative. In this Personal View, we present an interactive, open-access database designed to support this effort. Functioning as a living repository of environmental impact assessments within health care, the HealthcareLCA database collates 152 studies, predominantly peer-reviewed journal articles, into one centralised and publicly accessible location, providing impact estimates (currently totalling 3671 numerical values) across 1288 health-care products and processes. The database brings together research generated over the past two decades and indicates exponential field growth.

Introduction

The homeostatic mechanisms that have maintained stable living conditions on Earth over the past 12,000 years are increasingly disrupted by human activity. Anthropogenic environmental change poses a serious threat to both global health and health equity. Nearly 7 million deaths are attributable to air pollution annually, with per capita air-pollution-related deaths nearly four times higher in low-income countries than in high-income countries. If left unabated, greenhouse gas emissions could result in up to 83 million excess global deaths between 2020 and 2100, due to heat stress alone. Therefore, political and economic decision making over both global health and health equity.

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cycles.\textsuperscript{20,21} The Working Group for Environmental Sustainability in Clinical Care has highlighted the need for a central repository of health-care sustainability literature.\textsuperscript{22} Both the feasibility and cost-effectiveness of living evidence platforms were further emphasised in a 2021 review examining ways to support adaptation-related and mitigation-related decision making regarding the health impacts of climate change.\textsuperscript{21}

In this Personal View, we introduce a global living database of environmental impact assessments within health care, designed to serve as an evidence resource for health-care professionals, sustainability researchers, and policy makers. We begin by outlining the methods used to develop the HealthcareLCA database before providing an overview of its scope and coverage. These steps are followed by an analysis of available health-care-related environmental impact assessments across various scales. We discuss the implications and limitations of the current evidence base and summarise directions for future research.

Methods
Search strategy and selection criteria
A pragmatic, systematised approach for identifying studies that evaluate health-care-related environmental impacts was developed. A 2021 review of surgical LCAs by some of the authors of this Personal View provided an initial pool of 44 relevant studies that were identified via a systematic, protocol-driven approach.\textsuperscript{23} Iterative citation networking was then used to expand this pool, with Google Scholar functioning as the index for both forward and backward citation searching. Research and articles published between Dec 1, 2000, and Dec 11, 2021, were included. Searches were done between May 12, 2020, and Dec 31, 2021. Citation alerts were created within Google Scholar for each study selected for inclusion within the HealthcareLCA database to enable prospective citation searching. Supplementary alert systems within three bibliographic databases (Scopus, PubMed, Embase) were also created in May, 2020, and continue to be monitored (appendix p 3). Studies were included if they used LCA to quantify environmental impacts associated with one or more health-care products (eg, equipment, pharmaceuticals, and other products) or processes (eg, investigations, interventions, services, companies, industries, and health systems). Studies were excluded if they did not use LCA-based environmental accounting methods, had not been formally published (eg, preprint articles), or reported results that were superseded by another study by the same author group (eg, conference papers subsequently published as journal articles).

Data extraction and analysis
For each study selected for inclusion within the HealthcareLCA database, data relating to assessment scope, methodological design, results, and study interpretation were extracted and tabulated into a relational database management platform (Airtable, CA, USA). Captured data fields and accompanying definitions were based on important methodological elements as described within key LCA reporting guidelines, namely the International Organization for Standardization’s 14040:2006 and 14044:2006 standards\textsuperscript{17} and the Greenhouse Gas Protocol product lifecycle accounting and reporting standard.\textsuperscript{11}

Results
The HealthcareLCA database
The HealthcareLCA database acts as a centralised, open-access repository for health-care-related environmental impact assessments, spanning two decades of research. As of Dec 31, 2021, the database included 152 studies, providing 3671 numerical impact values for 1288 health-care products and processes across a broad range of environmental parameters. Collectively, these studies have been authored by a total of 638 authors from 286 institutions (appendix p 9).

Studies were mainly derived from peer-reviewed academic journals, including original research articles (n=132, 87%), reviews (n=4, 3%), conference papers (n=2, 1%), correspondence pieces (n=1, 1%), and letters (n=1, 1%), although a small proportion of studies were sourced from within the grey literature, including reports (n=6, 4%) and theses (n=6, 4%). Around half of all studies were published in the past 3 years (n=84, 55%), indicating rapid growth in the application of environmental impact assessment tools within the health-care sector (figure 1).

Most studies quantified environmental impact contributions from health-care products (n=61, 40%), followed by pharmaceuticals (n=28, 18%), procedures (n=17, 11%), systems (n=17, 11%), services (n=13, 9%), medical interventions (n=7, 5%), clinical investigations (n=5, 3%), randomised controlled trials (n=2, 1%), companies (n=1, 1%), and industries (n=1, 1%; figure 1A). Most studies were specific to medicine (n=43, 28%) or surgery (n=33, 22%), followed by pharmacy (n=21, 14%), dentistry (n=7, 5%), academia (n=2, 1%), and public health (n=1, 1%), whereas 45 (30%) were not specific to any one health-care field (figure 1B). Infectious disease (n=17, 11%), anaesthesiology, emergency medicine and intensive care (n=14, 9%), respiratory medicine (n=9, 6%), obstetrics and gynaecology (n=7, 5%), ophthalmology (n=7, 5%), and dentistry (n=7, 5%) were the most studied health-care disciplines in included analyses.

Most studies assessed health-care products or processes in Europe and Central Asia (n=62, 41%) or North America (n=43, 28%), with fewer assessments based in other world regions (figure 1C). Nearly 90% of studies were based in countries with either high-income (n=127, 84%) or upper-middle-income (n=7, 5%) economies, according to World Bank classification (figure 1D). Up until Dec 31, 2021, environmental impacts of health-care products and processes have been examined in 77 countries (appendix p 10).
Regarding methodological design, nearly three-quarters of included studies (n=109, 72%) took a bottom-up approach to their analysis with process-based activity data and emissions factors, whereas 19 (13%) took a top-down approach with financial activity data and EEIO emissions factors. 24 (16%) studies used a hybrid method, combining elements of top-down and bottom-up approaches. Nearly all studies assessed GWP (n=151, 99%) and more than half assessed at least one other mid-point impact category (n=83, 55%), with ozone depletion potential (n=51, 34%), photochemical oxidant creation potential (n=43, 28%), acidification potential (n=38, 25%), particulate matter formation (n=32, 21%), freshwater ecotoxicity potential (n=31, 20%), and eutrophication potential (n=27, 18%) among the most assessed non-GWP impact categories. Descriptive and methodological characteristics of studies included within the HealthcareLCA database as of Dec 31, 2021, are summarised within the appendix (pp 4–5).

Environmental impacts of global, regional, and national health-care systems

Several publications have reported environmental impacts of national and global health-care systems. In 2008, the Sustainable Development Unit (SDU) in the UK conducted the first such assessment, estimating the carbon footprint of National Health Service (NHS) England using an EEIO approach.24 The SDU have since conducted subsequent analyses to monitor progress towards NHS England’s goal of achieving net-zero carbon emissions by 2045.12,24 National level assessments have also been undertaken for health-care systems in Australia,25 Austria,26 Canada,27 China,28 Japan,29 and the USA,30–33 with health systems estimated to contribute between 3% (China)32 and 10% (USA28) of annual, country-level greenhouse gas emissions. Hospitals (responsible for 24–50% of total health-system emissions), pharmaceuticals (12–25%), and community health-care (10–23%) subsectors have consistently been identified as primary greenhouse gas emissions hotspots within these analyses (appendix p 11). Three studies also assessed national health-system contributions to non-GWP environmental impact categories.25,28,32 For example, in 2016, Eckelman and Sherman29 concluded that the USA health-care system contributes substantially to national acidifying emissions (SO\textsubscript{2}e; 12%), smog formation (O\textsubscript{3}e; 10%), and particulate matter pollution (PM\textsubscript{2.5}e; 9%). The impact that health-care pollution has on human health was assessed by three studies, with an estimated annual loss of 244 000–614 000 disability-adjusted life-years in the USA,33,43 and 4500–610000 disability-adjusted life-years in Canada.44

In 2019, Pichler and colleagues45 conducted the first international comparison of health-care system carbon footprints using an EEIO approach, reporting annual health-care sector CO\textsubscript{2}e emissions estimates for 36 countries between 2000 and 2014 (0·2–600 million metric tonnes [metric; Mt CO\textsubscript{2}e in 2014]). Karliner and colleagues46 expanded on this analysis to account for non-CO\textsubscript{2} greenhouse gas emissions, providing GWP estimates for 43 countries (0·2–550 MtCO\textsubscript{2}e per year) and the first GWP estimate for the global health-care system (2·0 gigatonnes [metric; Gt] CO\textsubscript{2}e, 4·4% of global annual net greenhouse gas emissions in 2014). The most up-to-date national-level and global-level health-care sector GWP estimates were within the 2021 report of the Lancet Countdown on health and climate change, which estimated that the global health-care sector was responsible for 2·5 GtCO\textsubscript{2}e in 2018 (4·9% of global greenhouse gas emissions), superseding estimates from the 2019 (2·3 GtCO\textsubscript{2}e, 4·6% in 2016) and 2020 (2·4 GtCO\textsubscript{2}e, 4·6% in 2017) Lancet Countdowns.2,36,37

Lenzen and colleagues48 conducted the first evaluation of global health-care provision with multiple environmental impact categories using an EEIO-based LCA approach and concluded that health care contributes 4·4% of global annual greenhouse gas emissions (2·4 GtCO\textsubscript{2}e), 3·6% of sulphur dioxide emissions (6·1 MtsO\textsubscript{2}), 3·4% of nitrogen oxide emissions (3·5 MtNO\textsubscript{2}), 2·8% of particulate matter emissions (3·4 Mt), 0·7% of malaria risk (0·81 million people), 1·7% of nitrogen to water (1·36 Mt), and 1·5% of scarce water use (7·3 teralitres), with data specific to 2015 for all impact categories. This analysis was the first to present disaggregated results by greenhouse gas type, revealing that nearly half of GWP from global health care is attributable to non-CO\textsubscript{2} greenhouse gas, including...
methane (22%), nitrous oxide (16%), fluorocarbons (8%), sulphur hexafluoride (2%), and nitrogen trifluoride (1%). In 2020, Lenzen and colleagues also concluded that the global health-care system’s environmental impact is increasing in absolute terms across all assessed parameters (1.1–3.1 times increase between 2000 and 2015). Although for many low-income and lower-middle-income countries this trend will represent increasing health-care investment and improved patient outcomes, data from the 2021 Lancet Countdown show that the positive relationship between per-capita health-sector greenhouse gas emissions and health-care access and quality appears to cease at around 0.40 tonnes CO₂e, at which point further per-capita GWP increases do not correlate strongly with improvements in quality of health care. For example, France achieves a similar health-care access and quality index score as the USA with a fifth of the carbon footprint (in 2018, France contributed 0.32 tonnes CO₂e per capita, whereas the USA contributed 1.8 tonnes CO₂e per capita). Within the USA itself, a similar analysis found that per-capita health-sector greenhouse gas emissions were weakly associated with state-level health system performance. Together, these findings indicate that many high-income countries and regions could reduce health-sector pollution without compromising quality of care. Considerable variability exists among available per-capita GWP estimates for national health-care systems (figure 2).

**Environmental impacts of health-care activities**

The HealthcareLCA database currently contains 29 studies that report environmental impact estimates for health-care activities, including procedures (n=17, 59%), medical interventions (n=7, 24%), and clinical investigations (n=5, 17%). Approximately half of all studies evaluating health-care activities (n=16, 55%) used process activity data and emissions factors (ie, a bottom-up approach), whereas ten analyses (34%) took a hybrid approach, and three (10%) used financial activity data and EEIO emissions factors (ie, a top-down approach). All activity-level analyses used an attributional lifecycle accounting method, whereby environmental flows to and from a system are analysed and a share of total impact is attributed to the functional

![Figure 2: Annual per capita GWP estimates for national, regional, and global health-care systems](https://www.thelancet.com/planetary-health)

Data are reported for the most recent year available within each analysis. The year of analysis can make a considerable difference to study results, especially for those nations that have experienced major currency fluctuations (given that the underlying input–output models depend upon economic transactions between sectors at a national or international level). The underlying input–output models have different constructions, which is also known to influence results. For these reasons, direct comparison of numerical values from different studies is inadvisable. The vertical dotted red line indicates global average health-care greenhouse gas emissions per capita. The horizontal grey lines connecting data points indicate the range of available estimates. Previous studies by the same author groups were excluded to avoid counting twice. Analysis by Pichler and colleagues only considered carbon dioxide emissions. Data for Pichler and colleagues are specific to 2014, except for estimates for Israel (2013) and New Zealand (2007). Chung and Meltzer, Nansai and colleagues, and Malik and colleagues only reported national-level health-care greenhouse gas emissions and per capita health-care emissions were calculated with World Bank population estimates specific to the relevant country and year. Romanello and colleagues reported global health-care greenhouse gas emissions as a proportion of total global greenhouse gas emissions (4.9%) in 2018, and as a percentage change relative to 2017; data from the 2019 and 2020 Lancet Countdown reports were used, alongside World Bank estimates for the global population in 2018, to estimate per capita global health-care greenhouse gas emissions. Estimates for Greenland and Curacao originally reported by Lenzen and colleagues were excluded from this figure because they were considered outliers (Greenland: 68 tonnes CO₂e per capita, Curacao: 15 tonnes CO₂e per capita). GWP=global warming potential. CO₂e=carbon dioxide equivalents.
unit, except for one analysis that followed a consequential LCA approach, whereby environmental consequences of altered demand for a product or activity are analysed. Most activity-level studies (n=18, 62%) were limited in scope to assessing contributions to climate change (ie, carbon footprint), whereas 11 analyses reported contributions to at least one other environmental impact category.10–41

Environmental impacts have been assessed across a number of surgical procedures, including abdominoplasty,46 breast augmentation,49 caesarean section, compared with vaginal delivery;44 cardiac surgeries;51 cataract surgery, including phacoemulsification and manual small incision approaches;40,46,52–54 endometrial staging, comparing laparotomy, laparoscopy, and robotic approaches;55 fundoplication, compared with medical management for gastro-oesophageal reflux disease;56 hysterectomy, comparing vaginal, abdominal, laparoscopic, and robotic approaches;57–59 intravitreal injections;58 laparoscopy and robotic laparoscopy;60 rhinoplasty;61 and skin cancer excisions.62 The carbon footprint of surgical procedures ranged 5·9–1000 kg CO2e per procedure, with anaesthetic gas use, energy consumption—principally for heating, ventilation, and air conditioning—and the production of single-use surgical equipment constituting the primary greenhouse gas emissions hotspots (figure 3). The GWP of a number of dental interventions have also been reported (eg, examinations, extractions, crowns, fillings, endodontic treatments, and denture placements), with estimates ranging between 0·73 kg CO2e and 71 kg CO2e per procedure (figure 3).63–65 The extent to which variation across surgical and dental procedures is because of methodological (eg, system boundary), contextual (eg, geographical setting), and procedural (eg, operation type or approach) differences is difficult to ascertain. Extant reviews of environmental assessments within surgery conclude that available studies vary substantially in terms of their quality and completeness.65–68

Environmental impact assessments have been undertaken for the medical management of type 2 diabetes (0·018–0·43 kg CO2e per patient day),51 gastro-oesophageal reflux disease (0·27 kg CO2e per patient day),51 septic shock in an intensive care setting (180–620 kg CO2e per patient day),69 general, spinal, and combined anaesthesia during total knee joint replacement (15–19 kg CO2e per procedure),70 various dialysis techniques and regimes, including in-centre and at-home daytime ambulatory peritoneal dialysis,71 continuous ambulatory peritoneal dialysis,71 and haemodialysis72–74 (5·0–28 kgCO2e per patient day of haemodialysis; appendix p 6).

Three studies evaluated environmental impact contributions from common radiological imaging methods, including radiograph,75 ultrasound,76 CT,77 single-photon emission tomography,86 and MRI10–12 (GWP range: 1·1–20 kg CO2e per imaging study; appendix p 6). Among studies that compared different methods for abdominal imaging78 and cardiac imaging, MRI consistently had the largest per-scan environmental footprint across multiple impact categories, followed by CT or single-photon emission tomography, and then ultrasound. Three studies have evaluated environmental impact contributions from laboratory investigations, including collection and analysis of common haematological tests (0·00050–0·27 kg CO2e per test),88,89 urinalysis (0·54 kg CO2e per test),12 and surgical biopsies (0·26–0·29 kg CO2e per biopsy jar processed; appendix p 6).69 Consumables constituted the main GWP hotspot for haematological tests (36–95%)70,71 and surgical biopsies (36–38%),69 and analyser electricity use was the main hotspot for urinalysis (35%).89

Environmental impacts of health-care products
Product-level analyses account for more than half of all studies housed within the Healthcare LCA database (n=89, 59% of 152), and principally consist of studies assessing impacts of health-care equipment (n=54, 61% of 89) or pharmaceuticals (n=28, 31% of 89). All product-level analyses utilised an attributional lifecycle accounting method, except for two that followed a consequential LCA approach.70,71 A single study used financial activity data and EEIO emissions factors (ie, a top-down approach),72 whereas the remainder used process activity data and emissions factors (ie, a bottom-up approach). Unlike assessments undertaken at other scales, product-level analyses tended to quantify impacts across multiple environmental parameters, with less than one-third of studies (n=25, 28% of 89) limited in scope to measuring GWP alone.

Many studies have reported the environmental impacts of equipment across a broad range of health-care fields, including anaesthetic equipment (central venous catheter insertion kits;73 drug trays;74 laryngeal mask airways [LMAs];75–78 laryngoscopes;79 and breathing circuits, face masks, LMAs, and laryngoscopes80); dental equipment (burs81 and x-ray systems82); medical equipment (bedpans,83 blood pressure cuffs,84 cardiac monitoring devices,85 custom packs for delivering infants,86 electrophysiology catheters,87 vaginal specula,88 pulse oximeters, and deep vein thrombosis compression sleeves);89 personal protective equipment (surgical gowns,90,91 scrub suits,92,93 surgical drapes,94 isolation gowns,95,96 medical aprons,97 face masks,98,99 face shields,89 gloves,99,100,101 and personal protective equipment kit);102 and surgical equipment (bronchoscopes,103 endoscopic trocars, ultrasonic scalpels, arthroscopic shavers, and endoscopic haemostasis devices;104 laparoscopic scissors, ports, and clip applicators;105 minimally-invasive prostate surgery devices;106 scissors;107 sharps containers;108–110 suction receptacles;111 and uretroscope112). Equipment-related environmental impacts were mostly reported on a per-use basis, with GWP
estimates ranging 0·0028–4·5 kg CO₂e for reusable items, 0·38–0·93 kg CO₂e for mixed items (ie, predominantly reusable with single-use components), and 0·0018–18 kg CO₂e for single-use items (figure 4).

Among studies comparing single-use and reusable, or mixed, items (n=36), three-quarters found that reusable equipment was associated with lower carbon footprint.96–100 Nine studies found

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<th>CO₂e (kg)</th>
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<td>Dental examination (Sweden)**</td>
<td>0·0028–4·5</td>
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<td>Cataract surgery* (India)**</td>
<td>0·0018–18</td>
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<td>Root canal procedure (Sweden)**</td>
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<td>Non-precious metal dental crown (UK)**</td>
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<td>Cataract surgery (UK)*</td>
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<td>Intravitreal injection, including pharmaceutical agent (Ireland)*</td>
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<td>Robotic hysterectomy (USA)*</td>
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<td>Antireflux surgery (UK)**</td>
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Phacoemulsification cataract surgery (India)**
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MSICS (Mexico)**
MSICS (Eswatini)**
Phacoemulsification cataract surgery (Eswatini)**
Phacoemulsification cataract surgery (Mexico)**
Phacoemulsification cataract surgery (New Zealand)**
Phacoemulsification cataract surgery (Hungary)**
Phacoemulsification cataract surgery (New Zealand public health-care system)**
Phacoemulsification cataract surgery (New Zealand private health-care system)**
Skin cancer excision (Australia, clinic-based)**
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Scenario of ideal laparoscopic hystereotomy (USA)**
Vaginal hysterectomy (USA)**
Abdominal hysterectomy (USA)**
Laparoscopic hysterectomy (USA)**
Robotic hysterectomy (USA)**
Antireflux surgery (UK)**

Global warming potential per procedure (kg CO₂e)

**Absolute impact values and relative contributions made available via corresponding author.

#Analysis only considers CO₂ for abdominal insufflation (ie, capture, compression, packaging, transportation, and use) and disposal of surgical instruments (ie, laparoscopic trocars). All other emissions sources were considered equivalent to open surgery or laparotomy (ie, only additional emissions associated with a laparoscopic approach were estimated). $Life cycle stage boundaries, lifecycle stages considered.

Figure 3: Carbon footprint of surgical and dental procedures

Direct comparison between procedures of which associated carbon footprint estimates were assessed by different studies is not advised due to considerable methodological heterogeneity among included studies (eg, variability in system boundaries, lifecycle stages assessed, and inventory databases, and characterisation methods used). This figure expands upon those previously published within Drew and colleagues and Rizan and colleagues. HVAC=heating, ventilation, and air conditioning.

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that the carbon footprint of reusable items was equivalent to, or higher than, that of single-use items, with key determinants including institutional reliance on coal-based electricity for reprocessing reusable items, stricter assumptions regarding the lifetime number of uses for reusable equipment, less efficient reprocessing assumptions (eg, smaller machine loads or washing items individually), and the comparison of multiple reusable instrument sets with a single, procedure-specific disposable set. The production phase was the primary greenhouse gas emissions hotspot for single-use equipment, and the reprocessing phase (ie, decontamination or laundering) was the primary greenhouse gas emissions hotspot for reusable equipment. A 2021 review of surgical equipment concluded that the provision and use of single-use surgical equipment tends to have a larger environmental impact across a broad range of parameters, including GWP, acidification, eutrophication, ozone depletion, and smog formation, compared with equivalent reusables.

Environmental impacts have been evaluated for a range of pharmaceutical agents, including anaesthetics, analgesics, antibiotics, antiinflammatories, antidepresants, bronchodilators, inhaled corticosteroids, medical oxygen, monoclonal antibodies, muscle relaxants and reversal agents, phosphodiesterase inhibitors, sedatives, sympathomimetics, vitamins, and vaccines. Impacts were most commonly reported by kilograms of active pharmaceutical ingredient, with wide-ranging estimates (2·3 kg CO₂e for naproxen to 280 000 kg CO₂e for nivolumab; appendix pp 7–8). This choice of functional unit has restricted utility for enabling the comparison of environmental impacts among pharmaceuticals with equivalent clinical indications because of underlying pharmacodynamic and pharmacokinetic differences. To inform clinical decision making, the comparison of pharmaceutical agents with similar indications and uses will require selection of more nuanced functional units, such as the maintenance of minimum alveolar concentration for one hour (for anaesthetic agents) and the management of pain in one adult over a designated treatment period (for analgesics). Several studies have reported carbon footprints for various methods of respiratory pharmaceutical delivery, including metered dose inhalers (MDIs), dry powder inhalers (DPIs), soft mist inhalers (SMIs), and electric nebulisers. MDIs were consistently associated with larger per-dose carbon footprints than other inhalers (appendix p 7). Carbon hotspots include the release of hydrofluorocarbon-based aerosol propellants (during both inhaler use and disposal) for MDIs and raw material extraction and production processes for DPIs and SMIs. Whereas all hydrofluorocarbons are potent greenhouse gases, individual GWPVs vary considerably depending on chemical structure. The carbon footprint of MDIs with hydrofluorocarbon-152a aerosol is lower (0·0093–0·020 kg CO₂e per dose or actuation) than those with hydrofluorocarbon-134a (0·0082–0·33 kg CO₂e per dose or actuation) or hydrofluorocarbon-227ea (0·70 kg CO₂e per dose or actuation) aerosol. Reported lifecycle greenhouse gas emissions estimates for DPIs (0·0076–0·026 kg CO₂e per dose or actuation) and SMIs (0·0038–0·0065 kg CO₂e per dose or actuation) were typically lower than all types of MDI. One study comparing DPIs and MDIs with hydrofluorocarbon-152s aerosol reported impacts beyond carbon footprint. The study concluded that, despite their lower carbon footprint, DPIs had greater lifecycle environmental impacts for 11 of 12 non-GWP impact categories assessed, including acidification, eutrophication, human toxicity, ecotoxicity, smog formation, and fossil and mineral depletion.

Discussion

The HealthcareLCA database constitutes a global repository of environmental impact assessments within health care, summarising results from 152 studies published between 2000 and 2021, and covering 1288 health-care products or processes within 77 countries (figure 1). This Personal View advances the temporal coverage of the last major quantitative review of the environmental impacts of health care by 5 years and includes three times as many quantitative studies. This Personal View also covers environmental impacts of health care at all scales, from the global health-care sector (2·0–2·5 Gt CO₂e per year) and national health systems (estimates available for 73 countries, ranging 0·20–780 MtCO₂e per year), to dental and surgical procedures (0·73–1000 kg CO₂e per procedure), medical interventions (0·018–28 kg CO₂e per patient day), health-care products (0·0018–18 kg CO₂e per use), and pharmaceuticals (2·3–280 000 kg CO₂e per kg active pharmaceutical ingredient). The HealthcareLCA database summarises existing research with a degree of detail not previously seen within the field, documenting important methodological decisions, such as inventory database utilisation, method of characterisation, and LCA software utilisation, as well as study system boundaries, included lifecycle stages, and any additional analyses undertaken to aid interpretation of results. Unlike previous reviews within the field, the HealthcareLCA database also tabulates health-care-related contributions to numerous environmental parameters (ie, beyond carbon footprint), allowing for a more holistic evaluation of environmental co-benefits and potential trade-offs of various health-care products and processes. To our knowledge, the HealthcareLCA database represents the first effort to summarise the environmental impacts of health care within one centralised and publicly accessible location, with all data and associated charts housed under an open-access licence. The interactive nature of the database allows users to search, sort, filter, and group housed data according to their individual needs. We anticipate that the database will serve as a central access point for...
three primary audiences: (1) clinicians who want to understand and mitigate environmental impacts associated with their practice; (2) academics undertaking LCAs within health care who want to identify literature gaps and potential sources of inventory data for future analyses; and (3) policy makers who want to make informed decisions about potential sustainable health-care strategies. The prospective maintenance of the HealthcareLCA database is a key priority and systems have been developed to both identify and enter new studies into the database as they become available.
health-care settings has rapidly increased in recent years, with the number of available studies having more than doubled since 2019. Despite recent advancements within the field, the evidence base pertaining to the environmental impacts of health care, and consequently the coverage of this Personal View, encompasses only a small proportion of available health-care products and processes across few geographical settings. This Personal View reveals that the quantification of environmental impacts within health care lags behind other sectors. For comparison, a meta-analysis of global food system environmental impacts included 570 methodologically consistent studies, representing approximately 90% of global calorie intake.

Limitations
A formal systematic review and meta-analysis was not feasible due to inadequate data availability (ie, a small number of studies have assessed equivalent health-care products or processes) and the extent of methodological heterogeneity among identified studies. Studies included in the analysis varied considerably in terms of system boundary selection (affecting risk of truncation error whereby relevant processes are omitted), inventory database utilisation, and impact assessment method (ie, different characterisation models exist, and these also undergo periodic updating). Together, these factors restrict the extent to which environmental impact estimates can be meaningfully compared, even among studies assessing similar products or processes. However, generalisable principles can still be derived regarding impact hotspots and alternative products or processes that are typically associated with lower environmental impacts.

Rapid growth within the field indicates that meta-analyses might soon be possible, although data harmonisation efforts will almost certainly be required to increase comparability of selected LCA studies before the pooling of results.

Although the timely collation and dissemination of available health-care LCA data is critical to informing mitigation strategies and progressing toward emissions reduction pledges, there are also appreciable risks associated with assembling data within a new and publicly accessible context. One potential risk is that future HealthcareLCA users might draw premature, and possibly inaccurate, conclusions regarding the relative environmental impacts of various health-care products or processes. For example, some studies are known to have methodological flaws, and users who are unfamiliar with the nuances of LCA research are less likely to recognise these flaws than those who are more familiar. To mitigate this risk moving forward, the next stage of platform development will involve formulation of an expert consensus statement in relation to the conduct and reporting of health-care LCAs, which can then be used as a benchmark to critically appraise the quality of studies included within our database. Future incorporation of quality indices within our database will provide users with an indication of the reliability and validity of available data.

Future research
Key priorities for future research include the expansion of existing lifecycle inventory databases to include detailed material and energy flows for common health-care items, the incorporation of non-GWP environmental indicators within future assessments, and the prioritisation of under-researched geographical areas (ie, the Middle East, north Africa, Latin America, and south Asia). Improving standardisation among health-care LCA studies presents a major challenge for the field moving forward, especially given the degree of diversity among available health-care products and processes, and the non-prescriptive nature of current LCA standards.

Although health-care-specific carbon footprint guidelines do exist, they are predominantly designed for industry reporting rather than academic research. Developing consensus-based methodological approaches and reporting frameworks for future health-care LCAs conducted at different scales is therefore another important research priority.

Conclusion
While responding to the growing burden of environment-related disease and adapting to increased supply chain disruption, resource scarcity, and infrastructure damage caused by environmental change, the global health-care system must simultaneously quantify and curtail its own environmental footprint. The HealthcareLCA database functions as a global living repository of health-care environmental impact assessments, providing an interactive and open-access evidence resource intended to inform and monitor progress towards sustainable health-care systems globally.

Contributors
All authors were involved in study conceptualisation, methods, and database design. JD was responsible for project administration, data curation, and formal analysis. JD and CR wrote the manuscript, and all authors were involved in the review and editing process.

Declaration of interests
We declare no competing interests.

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